The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 2

The tree house detectives continue to search for a way to lift Jacob into the tree house. Dr. D asks them to meet him at the circus to learn more about simple machines. They are not quite sure what a circus has to do with simple machines, but they know if Dr. D is there, it will be fun. After the circus, they decide that pulleys might be helpful in lifting Jacob. They discover on the Internet that NASA uses pulleys to lift the Space Shuttle onto the back of an airplane. To learn more about pulleys, they dial up Ms. Ennix, an aerospace engineer at NASA Dryden Space Flight Center in California. The tree house detectives feel that this is definitely the way to go but think they need to do a little more research. They visit Ms. Lisa Jones, an aerospace engineer at NASA Langley Research Center in Hampton, VA who uses pulleys to lift airplanes for crash tests at the gantry. Now they are certain that pulleys are the answer, but there are just a few little problems to overcome.

Objectives

The students will

- understand the principle of the Archimedes Screw.
- convert US customary units (feet) to metric (meters).
- understand and use simple machines.
- understand how simple machines change the direction of the force.
- learn how to combine simple machines to create compound machines.

Vocabulary

fulcrum – fixed point at which a lever pivots

gantry – a platform made to carry a traveling crane and supported by towers running on parallel tracks

lever – a bar that is free to pivot, or move about, a fixed point when an effort force is applied

load – something taken up and carried

load distance – the distance the load is moved

pulley – a small wheel with a grooved rim used with a rope or chain to change the direction of a pulling force and in combination to increase the force applied for lifting

screw – inclined plane wrapped around a cylinder to form a spiral

wedge – inclined plane that moves

wheel and axle – a simple machine consisting of a grooved wheel turned by a cord or chain with a firmly attached axle (as for winding up a weight) together with supports

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 2 of *The Case of the Powerful Pulleys*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 1 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 1. Use tools located on the Web, as was previously mentioned in Segment 1.
4. Focus Questions–Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.
5. What's Up? Questions–Questions at the end of the segment help students predict what actions the tree house detectives should take next in the investigation process and how the information learned will affect the case. These questions can be printed from the web site ahead of time for students to copy into their science journals.

View Segment 2 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the

Focus Question icon appears to allow students time to answer the question.

After Viewing

1. Have students reflect on the "What's Up?" questions asked at the end of the segment.
2. Discuss the Focus Questions.
3. Have students work in small groups or as a class to discuss and list what new information they have learned about force, energy, motion, work, and simple machines. Organize the information and determine whether any of the students' questions from Segment 1 were answered.
4. Decide what additional information is needed for the tree house detectives to determine the best way to get Jacob into the tree house. Have students conduct independent research or provide students with information as needed. Visit the NASA SCI™ Files web site for an additional list of resources for both students and educators.
5. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
6. If time did not permit you to begin the web activity at the conclusion of Segment 1, refer to number 6 under "After Viewing" on page 13 and begin the Problem-Based Learning activity on the NASA SCI™ Files web site. If the web activity was begun, monitor students as they research within their selected roles, review criteria as needed, and encourage the use of the following portions of the online, Problem-Based Learning activity:

   Research Rack - books, internet sites, and research tools

   Problem-Solving Tools - tools and strategies to help guide the problem-solving process

   Dr. D's Lab - interactive activities and simulations

   Media Zone - interviews with experts from this segment

   - listing of Ask-An-Expert sites and biographies of experts featured in the broadcast
7. Have students write in their journals what they have learned from this segment and from their own experimentation and research. If needed, give students specific questions to reflect upon as suggested on the PBL Facilitator Prompting Questions instructional tool found in the educator's area of the web site.
8. Continue to assess the students' learning, as appropiate, by using their journal writings, problem logs, scientific investigation logs, and other tools that can be found on the web site. Visit the Research Rack in the tree house, the online PBL investigation main menu section "Problem-Solving Tools," and the "Tools" section of the educator's area for more assessment ideas and tools.

Careers

aerospace engineer
circus performer
acrobat
space shuttle commander
pilot

Resources

Books

Hodge, Deborah: *Simple Machines.* Kids' Corner Press LTD, 1998, ISBN: 1550743112.

Richards, Jon: *Work and Simple Machines.* Cooper Beech Books, 2000, ISBN: 0761311599.

Riley, Peter D.: *Forces and Motion.* Heinemann Library, 2000, ISBN: 1575727722.

VanCleave, Janice Pratt: *Janice VanCleave's Machines.* Wiley, 1993, ISBN: 0471571083.

Whittle, Fran: *Simple Machines.* Raintree Steck-Vaughn, 1998, ISBN: 0817248900.

Web Sites

The Topic: Simple Machines
Looking for background information about simple machines? This site has it all. There are also six different activities you can complete to learn more about simple machines.
http://www.eduscapes.com/42explore/smplmac.htm

Simple Machines
Get a quick description of all six simple machines as well as great pictures. Each simple machine also has a link for more information.
http://sln.fi.edu/qa97/spotlight3/spotlight3.html

How Many? A Dictionary of Units of Measure
This site is an on-line dictionary for all units of measure from A-Z.
http://www.unc.edu/~rowlett/units/index.html

4000 Years of Women in Science
Women are, and always have been, scientists. This site lists over 125 names from our scientific and technical past. Biographies, references, and photographs are included on this site.
http://www.astr.ua.edu/4000WS/4000WS.html

Activities and Worksheets

Popcorn, Get Your Popcorn Up Here!

Problem

To learn the principle of Archimedes' Screw

Background

One of the first people to use a screw to lift was the ancient Greek scientist Archimedes. He invented a screw pump that could raise water from a lower level up to a higher level, making it flow against the force of gravity. Even though Archimedean screws were first built more than two thousand years ago, they are still used today. African farmers use them to irrigate their crops by lifting the water from the river into raised irrigation canals. The pumps are usually powered either by animals or by hand.

Materials

- one 1/4" wooden dowel
- glue
- 2 empty two-liter bottles with caps
- tag board
- scissors
- compass
- small tack
- popped popcorn
- metric ruler
- hole punch
- hammer
- two bowls

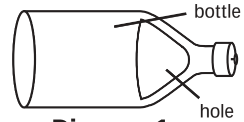


Diagram 1

Teacher Prep

Cut the bottom off each bottle. Near the top of each bottle, cut a triangular hole. See diagram 1

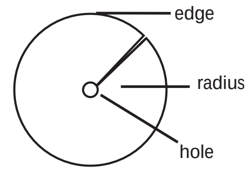


Diagram 2

Procedure

1. Measure the diameter of the 2-liter bottle.
2. Using the compass, measure and draw seven circles that are 2 mm smaller than the diameter of the bottle. Mark the center of each circle.
3. Using scissors, carefully cut out each circle.
4. Using the ruler, draw a line from the center of the circle to the edge (radius).
5. Cut from the edge to the center, being careful not to cut through the middle point.
6. Separate the edges of the cut and use a hole punch to make a hole at the center mark of the circle. See diagram 2.
7. To join the circles, place two circles on top of each other so that the slits line up. Glue the right edge of the slit on the bottom circle to the slit that is on the left edge of the top circle.
8. Continue this pattern until all seven have been joined to create the screw.
9. Slide the dowel through the holes of all seven circles.
10. Stretch the circles along the dowel.
11. Glue the slits at the top and the bottom of the screw firmly to the dowel. See diagram 3.
12. Push a small tack through the cap of the bottle. It may be necessary to use a hammer.
13. Screw the cap onto the bottle.
14. Place the completed screw into the bottle.
15. To hold the screw in place, press the end of the dowel firmly into the tack. It may be necessary to use a hammer to tap it into place. See diagram 4.
16. Place the bowls at two different elevations.
17. Put the popcorn in the lower bowl.
18. Place the end of the screw that has the cap into the bowl of popcorn.
19. Begin to twist the dowel and watch the popcorn as it rises up to the top of the pop bottle. When it reaches the top it should fall into the bowl that you placed at a higher elevation. See diagram 5.
20. Enjoy the popcorn.

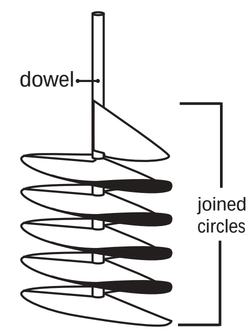


Diagram 3

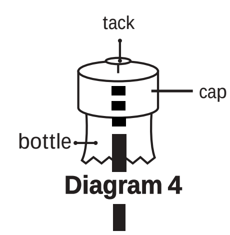


Diagram 4

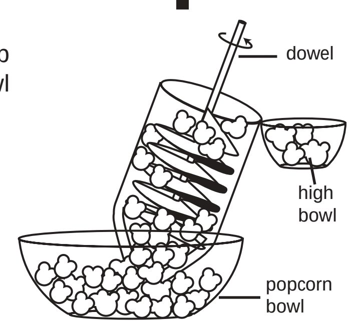


Diagram 5

Conclusion

1. Explain how the screw raised the popcorn.
2. Why would this type of device be used today?
3. Research Archimedes and write a brief paragraph about his life.

Sizing It Up

Problem

To learn how to convert customary units of measurement to SI/Metric units

Materials

yardsticks
meter sticks
inch/centimeter rulers
quart container
liter container
1 lb weight
1 kg weight
conversion chart
science journal

Procedure

Two students, Mike and Dan, have created a very large science fair project. They need to solve several problems.

- First, they are concerned that the project is not going to fit through the door. They have measured the doorway and found that it is 84 inches high and 48 inches wide. When they measured the project, which happens to be a rectangular prism, it was 180 centimeters tall, 90 centimeters wide, and 1 meter deep.
- Second, they need 5 liters of water to go with their project and all they have are quart containers.
- Third, the table where they are to display their project will only hold 25 pounds. Their project is 15 kilograms. Will they need a different table?

1. Compare and contrast an inch and a centimeter. Record your observations in your science journal.
2. Compare and contrast a meter stick to a yardstick? Record your observations in your science journal.
3. Look at the conversion chart and discuss with your group how to solve the first problem.
4. Solve the problem and record the answer in your science journal.
5. Compare and contrast quarts and liters. Record your observations in your science journal.
6. Discuss how to solve the second problem and record answer in journal.
7. Compare and contrast pounds and kilograms. Record your observations in your science journal.
8. Discuss how to solve the third problem and record answer in journal.
9. Discuss with your group what Mike and Dan should do to have a successful science fair experience. Write your conclusions in your science journal.

When you want to convert:	Multiply by:	To find:
Length		
inches (in)	2.54	centimeters
centimeters (cm)	0.39	inches
feet (ft)	0.30	meters
meters (m)	3.28	feet
yards (yd)	0.91	meters
meters (m)	1.09	yards
miles (mi)	1.61	kilometers
kilometers (km)	0.62	miles (mi)
Mass and Weight*		
ounces (oz)	28.35	grams
grams (g)	0.04	ounces
pounds (lb)	0.04	kilograms
kilograms (kg)	2.2	pounds
Volume		
liters (L)	1.06	quarts (qt)
liters	0.26	gallons
gallons (gal)	3.78	liters

*Weight as measured in standard Earth gravity
**Abbreviations are in parentheses.

Conclusion

1. When would you use conversion charts in your daily life?
2. Why would the tree house detectives have to convert some of their measurements?

Extension

Students should be given an opportunity to create problems similar to the ones above and share them with the class to solve. Create problems using volume, temperature, and area.

Keeping It Simple–Six Simple Machines

Problem

To explore and use simple machines to understand how they make "work" easier

Teacher Note

This activity is divided into six stations where six small groups will rotate through each station to explore and use simple machines. This exploration may be completed over 2-3 days. To set-up the activity:

1. Gather and set up materials for each station as listed.
2. Number the stations.
3. Copy student procedure directions for each station and place on appropriate table.
4. Divide students into six groups and pass out Simple Machines Data charts 1 and 2 (pp. 34 and 35).
5. Assign each group a station and explain how to rotate through the stations. Station 1 will move to Station 2, and so on.
6. It may be helpful to set a timer so that students will all rotate at the same time.
7. At the end of the activity, discuss the questions and the various simple machines.

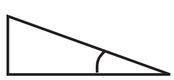
1) Inclined Plane

Problem

Which ramp will make moving a large piece of furniture the easiest?

Procedure

1. Attach the spring scale to the string around the paperback books.
2. Lift the books with the spring scale.
3. Read and record on the data sheet the number of grams it took to lift the books.
4. Use the wooden plank or cardboard and the protractor to construct a ramp that has a 60-degree angle. Put one end of the inclined plane on a stack of books. Pull the books up the inclined plane, keeping the spring scale parallel to the ramp.
5. Read and record in the Data Chart 1 (p. 34) the number of grams needed to move the books up the ramp.
6. Repeat steps 4-5 using a 30-degree inclined plane



Ramp with 60-degree angle

Materials

Inclined Plane
wooden plank or sturdy piece of cardboard
stack of books
protractor
2 paperback books tied together with string
spring scale

Questions

1. Did the ramp make the work easier?
2. Which ramp made the work easiest? Why?
3. What happened to the length of the inclined plane as the angle became smaller?
4. How can you use an inclined plane to help you in everyday life?

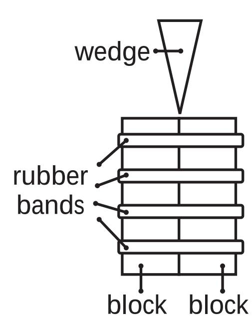
2) Wedge

Problem

How can a wedge help separate two objects?

Procedure

1. Use the rubber bands to band the two same sized blocks of wood together. If you can easily pull them apart, add more rubber bands.
2. Use the smaller third block of wood to pry the banded blocks apart. Record your observations in Data Chart 1.
3. Use the wedge to pry apart the banded blocks. Record your observations in Data Chart 1.



Materials

Wedge
blocks of wood the same size
one smaller block
rubber bands
wedge of wood

Questions

1. What happened when you tried to separate the banded blocks with the smaller block of wood?
2. Compare what happened when you used the block and then the wedge to separate the banded blocks? Explain why there was a difference.
3. How can you use a wedge to help you in everyday life?

Keeping It Simple (continued) Six Simple Machines

3) Wheel and Axle

Problem

Does a larger handle on a screwdriver make work easier?

Procedure

1. Observe the screwdrivers and determine which part of the screwdriver is the wheel and which part is the axle. Discuss and record in Data Chart 1 (p. 34).
2. First, use the screwdriver with the smaller handle. Turn the screwdriver until about half the screw is inserted into the wood. Observe and rate the amount of force needed to turn the screw into the wood.
3. Use the second screwdriver to finish inserting the screw into the wood. Observe and rate the amount of force used. Record.
4. Compare the amount of force used in steps 2 and 3.

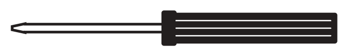
Materials

Wheel and Axle

two screwdrivers that are the same length but have different sized handles
piece of wood
6 screws (1 for each group)

Questions

1. Which screwdriver made it easier to insert the screw into the wood?
2. Explain you answer.
3. How can you use a wheel and axle in everyday life?



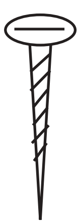
4) Screw

Problem

To understand that the pitch of a screw determines the difficulty of turning the screw

Procedure

Each group should use a new set of predrilled holes.



1. Observe each screw and nail and note any differences in Data Chart 2 (p. 35).
2. Place screw A in one of the predrilled holes.
3. Use the line drawn on top of the screw to count the number of turns it takes using the screwdriver to insert the screw entirely into the block of wood.
4. Record the number of turns in your data chart. Observe the amount of force used and record.
5. Repeat steps 2-4 with screw B.
6. Using just your hands, try to insert the nail into the wood. Use the line drawn on top of the nail to help you count the number of turns.
7. Record the number of turns and your observations in the data chart.
8. Compare and contrast inserting the nail, Screw A, and Screw B.

Materials

Screw

block of soft wood with 12 predrilled holes
6 nails (1 for each group)
6 sets of 2 wood screws with different pitch but equal length (pitch is the distance between the treads or ridges)
1. use permanent marker and draw a line across the top of each screw and nail
2. use tape to label screws A (larger pitch) and B (smaller pitch)

screwdriver
goggles

Questions

1. How did the nail work in relation to the two screws?
2. Did you find one screw works better than the other?
3. What was the difference between the screws?
4. Which one needed more turns? Why?
5. How can screws make a difference in everyday life?

Keeping It Simple (concluded) Six Simple Machines

5) Lever

Problem

How does moving the fulcrum affect the amount of force needed in a lever system?

Materials

Lever
30-cm ruler
dictionary
small object such as a pencil or base 10 block for fulcrum
spring scale

Procedure

1. Place the dictionary 26 cm from the edge of the table.
2. Place one end of the ruler under the dictionary so that the 1-cm mark is covered.
3. Place the fulcrum under the ruler at the 24 cm mark.
4. Attach the spring scale to the ruler so that it is hanging downward. Gently pull on the spring scale until you just begin to lift the dictionary. See diagram 1.
5. Read and record in Data Chart 2 (p. 35) the number of grams used.
6. Keeping the 1-cm side of the ruler underneath the dictionary, move the fulcrum to the 15-cm mark. Repeat steps 4-5.
7. Repeat step 6, using 6 cm as the fulcrum's position.

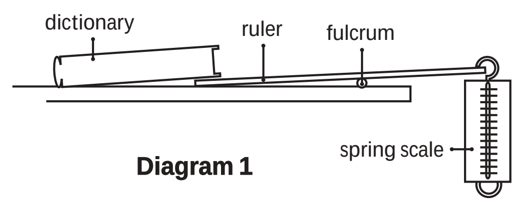


Diagram 1

Questions

1. Did the number of grams used to lift the dictionary change when you moved the fulcrum? How?
2. If you wanted to lift a heavy load, where should you place the fulcrum?
3. How can you use levers to help you in everyday life?

6) Pulley

Problem

How do pulleys make work easier?

Materials

Pulley
two single pulleys
ring stand
500 g weight
80 cm of string
spring scale

Procedure

1. Use the spring scale to lift the weight off the floor or desk. Read and record the number of grams.
2. Attach the pulley to the ring stand.
3. Attach one end of the string to the weight.
4. Loop the other end through the pulley and attach the spring scale to the end of the string. See diagram 1.
5. Pull down on the spring scale to measure how many grams are needed to lift the weight and record in Data Chart 2 (p. 35).
6. Using a second pulley, construct the pulley system below. See diagram 2.
7. Pull up on the spring scale to lift the weight. Read and record grams in the data chart.

Questions

1. Was there a difference between not using a pulley and using one pulley?
2. What was the difference between using one pulley and using two pulleys?
3. Why would anyone want to use just one pulley?
4. How can pulleys help you in everyday life?

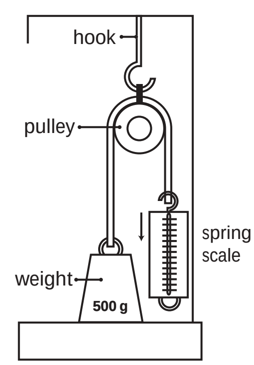


Diagram 1

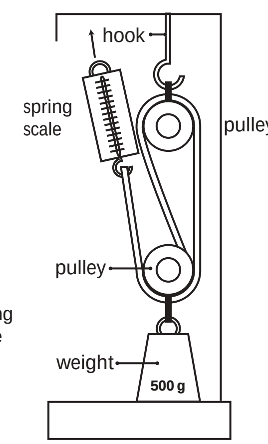


Diagram 2

Keeping It Simple Data Chart 1

Inclined Plane

Inclination in degrees	Grams
0 º	
30 º	
60 º	

Questions:

1. ____________________

2. ____________________

3. ____________________

Wedge

Object	Rate Observed Force
Small block	
Wedge	

Questions:

1. ____________________

2. ____________________

3. ____________________

Wheel and Axle

On a screwdriver, the wheel is the _________ and the axle is the _________.

Screwdriver	Rate the Observed Force
Small-handled screwdriver	
Large-handled screwdriver	

Questions:

1. ____________________

2. ____________________

3. ____________________

Keeping It Simple Data Chart 2

Screw

Observations (compare and contrast nail, screw A, and Screw B).

Screw	Number of Turns	Rate Observed Force
Nail		
Screw A		
Screw B		

Compare and contrast the insertion of screws A and B and the nail.

Questions:

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

Lever

Position of Fulcrum	Grams
24 cm	
15 cm	
6 cm	

Questions:

1. ____________________

2. ____________________

3. ____________________

Pulley

Number of Pulleys	Grams
0	
1	
2	

Questions:

1. ____________________

2. ____________________

3. ____________________

4. ____________________

Mission Possible

Problem

To understand that simple machines can change the direction of a force

Scenario

You are part of a rescue team that needs to get medical supplies to the other side of a flooded river. You don't have a boat and only a limited number of supplies that include a small piece of rope that is not long enough to reach the other side. You also have access to a large plank of wood washed up by the flood and a log. Your mission is to devise a plan to get the medical supplies to the people on the other side of the river.

Materials

30-cm ruler
pencil or marker
foam cup
string
scissors
tape
10 mini marshmallows
goggles

Procedure

1. Sort through your supplies: goggles, ruler (large plank), pencil (log), string (rope), mini marshmallows (bundles of medical supplies), tape, foam cup, and scissors.
2. Brainstorm how you are going to get the medical supplies to the other side.
3. Construct your solution using only the supplies provided.
4. If you are able to move your supplies 20 cm or more, then you have successfully completed your mission. If your bundles fall short of 20 cm, then the supplies have washed downstream. The group who gets the most bundles across the river "wins" the competition.
5. Present your solution to the class and discuss how and why you used this solution.

Conclusion

1. In your solution, did applying a force in one direction cause a force in another direction?
2. What other simple machines can change the direction of a force?
3. Write a paragraph explaining your activity and how you used the items to move the medical supplies. Explain the forces used and their change of direction.

Answer Key

Popcorn, Get Your Popcorn Up Here!

1. The screw lifted the popcorn when it changed the rotation or twisting of the dowel into upward movement.
2. This device would be used today as a simple and inexpensive way to irrigate crops by using river and lake water. It is also used in combine harvesters to lift grain into storage containers.
3. Answers will vary.

Sizing It Up

1. Answers will vary.
2. Answers will vary.

Keeping It Simple

Inclined Plane

1. Yes.
2. The 30-dregree ramp used the least amount of force to lift the weight. When you increase the height of the ramp, you increase the amount of force necessary to move the weight. For example, if you have a 500-g weight at a 30-degree angle, it might take 125 g to move it up the ramp. However, when the ramp is set at 60 degrees, you have to overcome more height, which results in using more force.
3. The length of the ramp increased as the angle became smaller.
4. Answers will vary but might include that ramps can be used to move furniture, help make places accessible to people in wheelchairs, and help cars go up steep mountains.

Wedge

1. The banded blocks could not be separated with the smaller block of wood.
2. The wedge was able to get between the banded blocks and separate them unlike the block. The wedge is thinner on one end and that allows it to fit in small, tight places.
3. Answers will vary but might include splitting firewood, loosening boards on a fence, and prying hubcaps off a tire.

Wheel and Axle

1. The screwdriver with the larger handle.
2. The ratio between the handle (wheel) and the shaft (axle) is larger on the larger handled screwdriver. With a larger ratio, you divide the weight by a larger number and get a smaller amount of force needed.
3. Answer will vary but might include a Ferris wheel, wheelbarrow, and moving boxes on rollers.

Screw

1. Unlike the screws, the nail was unable to go into the wood.
2. Screw B went into the wood easier than screw A.
3. The difference between the two screws was the distance between the threads. Screw B's threads had a smaller distance between them.
4. It took more turns to get screw B into the wood because you had to turn it over a longer distance since the pitch was smaller. Even though you had to turn Screw B more times, it made the force less. That is called a tradeoff.
5. Answers will vary, but might include securing items to a wall, connecting the stems of eye glasses to the frames, and putting machines together.

Lever

1. Yes. The farther away from the dictionary the fulcrum was moved, the more grams of force it took to lift it.
2. To lift a heavy load, place the fulcrum close to the load.
3. Answers will vary, but might include a seesaw, moving large rocks, and lifting a heavy item to slide something under it.

Pulley

1. No. The amount of grams (force) used was the same.
2. The amount of force needed to move the load decreased when using the two-pulley system.
3. You can use one pulley to change the direction of the force. It is easier to pull down than to lift up, so this makes work easier.
4. Answers will vary, but might include loading containers on and off boats, lifting heavy objects up to a second story building, and taking a motor out of a car.

Mission Possible

1. The solution to this problem is probably going to be the construction of a catapult, using the plank and the ruler to launch the supplies to the other side. As force is applied to one end of the plank, it creates a force on the other end of the plank, moving in the opposite direction. This device will then launch the supplies through the air and hopefully, to the other side.
2. Many other simple machines can change the direction of a force. For example, when using a single pulley, you pull down to move the load upward. When using a wedge, you push down to move the load laterally. When using a gear, you turn one gear to move another gear in the opposite direction.